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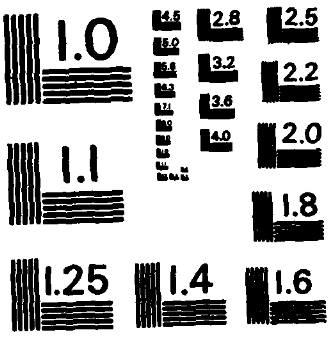

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Role of Small Computers in Two-Dimensional Flow Modeling

by D. Michael Gee

Technical Paper No. 108

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1

Role of Small Computers in Two-Dimensional Flow Modeling

by

D. Michael Gee* M.A.S.C.E.

Introduction

This paper describes the computational aspects and computer usage history of numerical simulations of horizontal, free surface, steady or unsteady two-dimensional flow fields. The focus is on a particular numerical model (RMA-2(6)) that has been in use and development at the Hydrologic Engineering Center (HEC) and elsewhere for the past decade (1, 2, 3, 4, 5, 7, 9). RMA-2 solves the complete Reynold's equations for turbulent flow in two dimensions using the finite element method. Terms describing bottom friction, surface wind, and Coriolis forces are included. Details of the governing equations and solution technique are thoroughly documented elsewhere (6). RMA-2 may be used as a driver for sediment transport and water quality simulations as well as for computing hydrodynamic information only. Additional keywords: Computational hydraulics; microcomputers; bibliographies.

Background

Throughout the development and application of two-dimensional flow models a major concern has been the magnitude of computational resources needed to perform the simulations. Indeed, one of the major components of the study of various numerical solution techniques has been that of computational efficiency (8). Historically, the use and study of multidimensional hydrodynamic models has been the realm of institutions having access to large, high-speed computers at discount rates. It is the author's position that the price/performance ratio of contemporary computers is such that two-dimensional flow modeling can now become a routinely used engineering tool (with associated needs for such important support items as training and user assistance). Furthermore, the high utilization of computational resources that continues to be needed in such studies is now an inconvenience rather than an unacceptable economic burden.

*Chief, Computer Support Center, The Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616

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Computational Aspects of RMA-2

Solution of the equations of motion for turbulent free surface flows requires substantial data manipulation. A finite element network describing the boundary geometry and bathemetry of the problem must be developed, encoded, stored, and manipulated. Numerical solutions must be viewed graphically, and summarized and interpreted conveniently. It is, however, the internal operations of the numerical solution technique that place the greatest demands on computational resources.

Application of the finite element technique produces a set of simultaneous nonlinear algebraic equations that must be solved iteratively. Typically there are several thousand of these equations in several thousand unknowns. The unknowns are the two velocity components and depth at each computational node. The efficiency of the soution of this set of equations dominates the efficiency of the entire simulation. RMA-2 takes advantage of a solution technique known as a front solver. The frontal solution technique requires rapid storage and retrieval of intermediate solution vectors. The virtual memory architecture of most minicomputers is well adapted to this process allowing intermediate solutions to be stored in large arrays rather than using programmed writes and reads.

History of Computers Used

Initial applications and testing of RMA-2 at the HEC were performed on a CDC 7600. Many applications and most of the development done at Resource Management Assoc. (Lafayette, CA) used a Prime 550. Work at the HEC and several Corps district offices over the past few years has been done using Harris 500 computers. Recently, the HEC has been evaluating the use of a Hewlett-Packard 9000 32-bit super-minicomputer for RMA-2 applications. Tests have indicated that execution times are only about 50% longer on the HP than on the Harris. This is perfectly acceptable for production work, particularly as use of an HP9000 type machine should not be at a cost proportional to run time.

This history indicates two things: (1) RMA-2 (and associated programs) is generalized and highly transportable among various types of computers, and (2) current price/performance indicators for machines such as the HP9000 are such that this type of numerical modeling is now economically available to much smaller institutions and consulting firms than previously.

A Typical Application

Results of a typical steady flow simulation are shown in Fig. 1. This is a reach of the upper Mississippi River that is about 2.2 miles (3.5 km) long and 1200 ft. (370 m) wide. This area was studied with high resolution network consisting of 375 elements and 1189 nodes. The study is described in detail in Ref. 4. Typical execution times for this problem on various computers are given in Table 1.

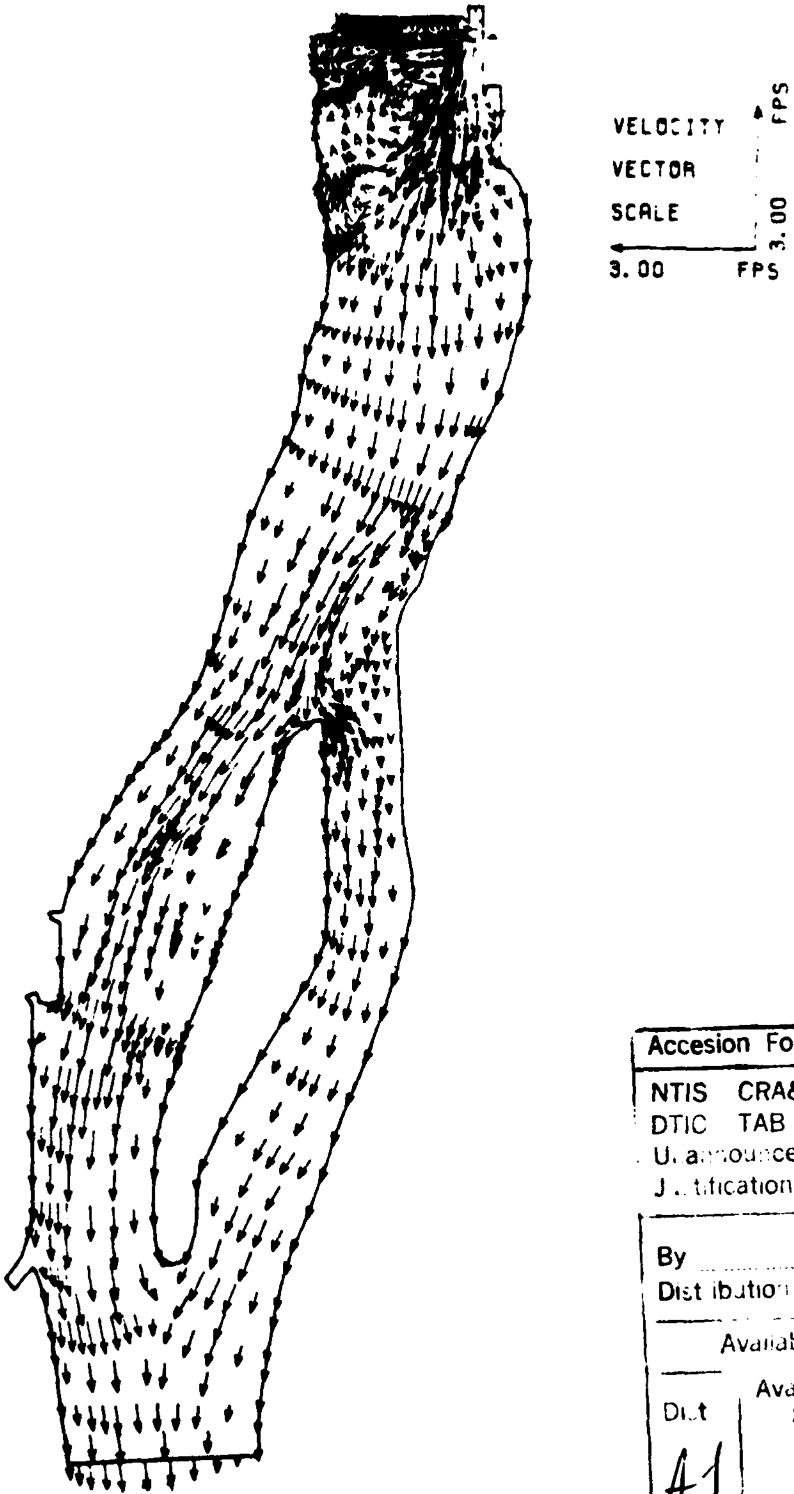

Figure 1
Example Vector Plot Upper Mississippi River,
Discharge = 10,000 cfs (280 cms)

Table 1 Typical Execution Times

Machine	Time
CDC Cyber 865	3.9 min
Harris 500	13.5 min
HP 9000	19.8 min

Importance of Pre- and Post-Processing

Production applications of numerical two-dimensional flow models immediately focus the modeler's attention on data handling and interpretation of results. Indeed, it is more accurate to think of RMA-2 as a modeling system rather than a single computer program. There exists a geometric data preprocessor (RMA-1) to aid in development and error checking of the finite element network; and graphics post-processors for displaying and interpreting simulation results. The linkages and data flow among the various elements of an RMA-2 based modeling system are shown on Fig. 2.

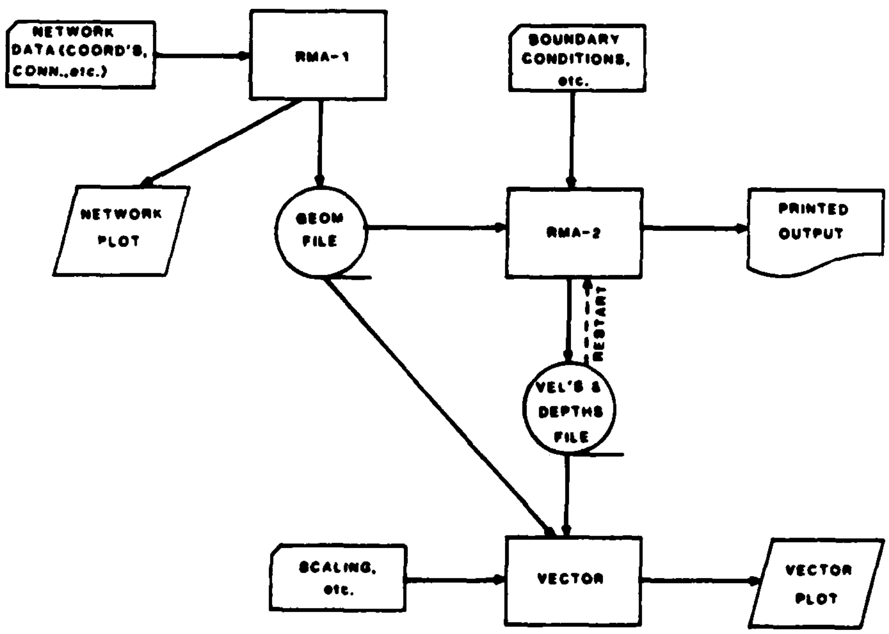

Figure 2
Data Flow and Program Linkage
for a Typical RMA-2 Application

It is a characteristic of the finite element method that the solution is continuous in space; contrasted with finite difference techniques that yield solutions at discrete points. This characteristic facilitates graphic displays (such as contouring) and leads to more accurate constituent transport computations. Types of graphical displays and their uses are numerous. The traditional format is that of the velocity vector plot (Fig. 1). Important as well are contours of velocity magnitude (isotachs) which can be used for habitat quantification (4). Contour plots of bottom elevation, primarily useful for checking network accuracy, and water surface elevation are also used. Pathline plots depict the traces of particles moving with the vertical average velocity. These plots are particularly useful in interpreting unsteady flow patterns such as tidal excursions. For open river situations a logarithmic velocity profile in the vertical can be fitted to the computed mean vertical velocity at each point to obtain quasi-three dimensional information (4).

Conclusions

1. The long history of successful applications and associated development of data error checking in the preprocessing phase of a two-dimensional flow study have produced a situation where minimal computational difficulties are encountered in RMA-2 applications.

2. Adequate computational resources exist in 32-bit minicomputers to perform finite element hydrodynamic simulations.

3. The largest payoff for future research lies in enhanced data preparation techniques and improved simulation post-processing rather than improved computational efficiency.

4. It is anticipated that microcomputers will play a useful role in data preparation and graphic display of simulation results. A particular need is for a truly interactive finite element generator that recognizes bottom topography as well as boundary shape.

Acknowledgements

The author wishes to recognize the assistance of and advice of Dr. Ian King and the late William Norton of RMA. Work reported herein was sponsored by various Corps of Engineers District offices and the Research and Development program of the Office, Chief of Engineers. The opinions and conclusions expressed herein are those of the author and not necessarily those of the U.S. Army Corps of Engineers. Manufacturers names are presented herein for example only and do not constitute a recommendation or endorsement by the author or the U.S. Army Corps of Engineers.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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